(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 770 182 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
27.08.2014 Bulletin 2014/35

(21) Application number: **13156508.7**

(22) Date of filing: **25.02.2013**

(51) Int Cl.:
F02C 7/224 (2006.01)
F02C 9/00 (2006.01)
F02C 9/40 (2006.01)
G01N 33/22 (2006.01)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(71) Applicant: **Alstom Technology Ltd**
5400 Baden (CH)

(72) Inventors:
- **Knapp, Klaus**
  5412 Gebenstorf (CH)
- **Marx, Peter**
  5413 Birmenstorf (CH)
- **Reyser, Karl**
  79790 Kuessaberg (DE)
- **Gasser-Pagani, Maria-Belen**
  5400 Baden (CH)

(54) **Method for adjusting a natural gas temperature for a fuel supply line of a gas turbine engine**

(57) The method for adjusting a natural gas temperature for a fuel supply line (6) of a gas turbine engine (1) comprises measuring by infrared analysis the natural gas percentage content of methane ($CH4$), ethane ($C2H6$), propane ($C3H8$), butane ($C4H10$), carbon dioxide ($CO2$), calculating the nitrogen ($N2$) percentage content as the complement to 100 of the measured percentage content of methane ($CH4$), ethane ($C2H6$), propane ($C3H8$), butane ($C4H10$), carbon dioxide ($CO2$), calculating an index indicative of the natural gas energy content, adjusting the natural gas temperature on the basis of the index.

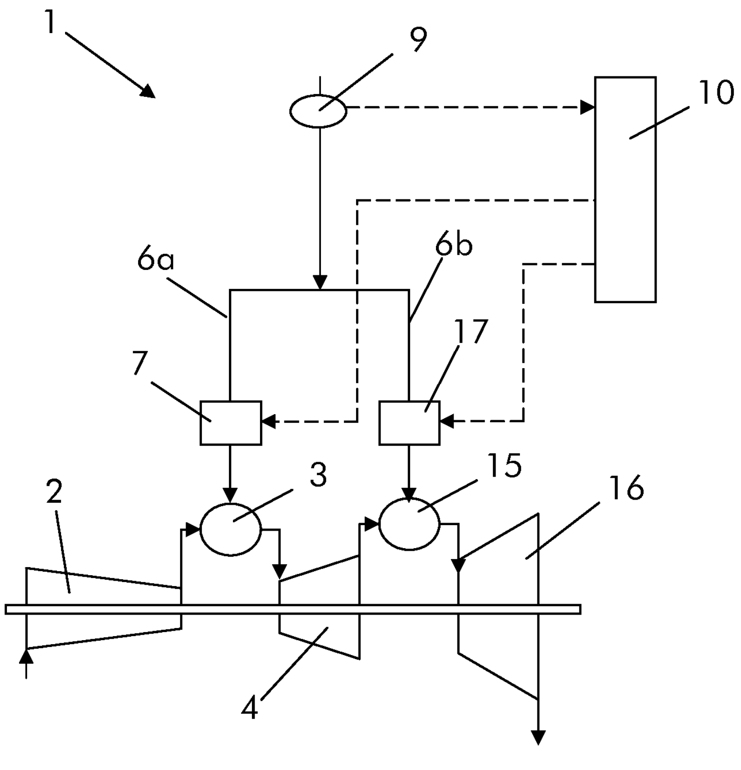

Fig. 2

EP 2 770 182 A1

Description

TECHNICAL FIELD

[0001] The present disclosure relates to a method for adjusting a natural gas temperature for a fuel supply line of a gas turbine engine and to a gas turbine engine.

BACKGROUND

[0002] Combined cycle power plants have a gas turbine engine and a steam turbine engine. The gas turbine engine can be supplied with natural gas that is pre-heated (i.e. its temperature is adjusted before it is injected into the combustion chamber of the gas turbine engine) to optimize efficiency; usually pre-heating is achieved by heating the natural gas to a maximum allowable temperature using steam or feedwater from the steam cycle.

[0003] Flexibility with regards to the natural gas composition is an important feature for those combined cycle power plants that are supplied from different natural gas pipelines, from a LNG harbour or from a pipeline where additionally a natural gas treatment plant is installed.

[0004] In general when the natural gas source is changed, the natural gas composition is also changed. Change in natural gas composition can cause a change in the behavior of the combustion process. For example, a natural gas with high inert contents and hence a lower heating value requires an increased supply pressure; this may lead to changes in gas reactivity and mixing quality.

[0005] For this reason the composition of the natural gas supplied to a combined cycle power plant (in particular to a gas turbine of such a plant) is measured.

[0006] In order to measure the composition of the natural gas, different devices are known, namely:

- Infrared analyzers, these devices allow measurement of the hydro carbons; in addition they have the advantage that their response is quite fast; this is useful because the natural gas supply (and thus the natural gas composition) can be changed on a weekly, daily or hourly basis or even much faster if for example in a LNP plant the higher hydro carbon trips according to the fuel supply conditions). Infrared analyzers have the disadvantage that they are not able to measure the natural gas content of nitrogen (N2, the N2 amount can be quite large in natural gas), because this compound does not respond to infrared radiation.
- Chromatography analyzers, these devices can measure the hydro carbon content and also the nitrogen (N2) content of the natural gas. The disadvantage of chromatography analyzers is that their response is very slow, because it can take minutes for them to analyze the natural gas composition. Such a slow response can lead to instability of the combustion in the gas turbine engine.

[0007] The changes in natural gas composition could happen slowly if the switch of gas line is planned (usually around 5-30 minutes) or they could happen quickly if an unplanned event triggers a change of natural gas (usually around 30 seconds).

SUMMARY

[0008] An aspect of the disclosure includes providing a method for adjusting the temperature of the natural gas (pre-heating temperature) to optimize reliability and efficiency.

[0009] Advantageously, for continuous reliable operation of a combined cycle power plant with fluctuating gas compositions at optimum combined cycle efficiency the actual gas composition is measured and a maximum allowable fuel gas temperature is defined and controlled for the fuel supply line or different fuel supply lines.

[0010] Advantageously, the method allows a fast response of the gas turbine engine operation to changes in composition of the natural.

[0011] These and further aspects are attained by providing a method and gas turbine in accordance with the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Further characteristics and advantages will be more apparent from the description of a preferred but non-exclusive embodiment of the method and gas turbine engine, illustrated by way of non-limiting example in the accompanying drawings, in which:

Figures 1 and 2 are schematic views of different gas turbine engines.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0013] The method for adjusting the natural gas temperature for a fuel supply line of a gas turbine engine comprises the following steps:

- measuring by infrared analysis the natural gas percentage content (preferably molar or volumetric percentage but also mass percentage) of methane (CH_4), ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), carbon dioxide (CO_2),
- calculating the nitrogen (N_2) percentage content as the complement to 100 of the measured percentage content of methane (CH_4), ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), carbon dioxide (CO_2); in other words:

$$[N2\%] = 100\% - [CH4\%] - [C2H6\%] - [C3H8\%] - [C4H10\%] - [CO25]$$

The largest part of the natural gas content is defined by methane, ethane, propane, butane, carbon dioxide and nitrogen, thus even if additional components such as argon are contained in the natural gas, they do not negatively affect the measure of nitrogen as for the precision required. In addition, since the hydro carbon content is measured by infrared analysis and the nitrogen content is calculated, the composition of the natural gas can be monitored with a fast response. Further steps of the method include:

- calculating an index indicative of the natural gas energy content, and
- adjusting the natural gas temperature on the basis of the index.

[0014] For example, adjusting the natural gas temperature includes defining a plurality of ranges for the index, associating one maximum temperature to each range, and maintaining the natural gas temperature below or at the maximum temperature corresponding to the range into which the calculated index falls. This can be advantageously done by means of look up tables. The look up tables can be prepared during the validation tests of the gas turbine engine.

[0015] In order to take into account the natural gas composition, the index can be calculated by:

- calculating the lower heat value of a mixture including the measured amount of methane (CH_4), ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), carbon dioxide (CO_2) and the calculated amount of nitrogen (N_2)
- calculating the molecular weight of the mixture including the measured amount of methane (CH_4), ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), carbon dioxide (CO_2) and the calculated amount of nitrogen (N_2). This can be done by summing the molecular weight of each component in view of its percentage in the mixture.

[0016] The index NGI (Natural Gas Interchange) is calculated by:

$$NGI = (LHVng/LHVch4) * (Mng/Mch4)^{1/2}$$

wherein
LHVng is the calculated lower heat value of the mixture
LHVch4 is the lower heat value of methane
Mng is the molecular weight of the mixture
Mch4 is the molecular weight of methane.
In this case the reference for the index is a fuel being methane.
Alternatively, the index can be calculated with reference to the design conditions for the gas turbine engine.
In this case the index IGN is calculated as follows:

$$NGI = (LHVng/LHVdes) * (Mng/Mdes)^{1/2}$$

wherein
LHVng is the calculated lower heat value of the mixture
LHVdes is the design lower heat value
Mng is the molecular weight of the mixture
Mdes is the design molecular weight.

[0017] If the gas turbine engine has a plurality of fuel supply lines for different combustion chambers and/or different stages of a combustion chamber the natural gas temperature of at least one fuel supply line can be adjusted independently of the natural gas temperature of another fuel supply line.

[0018] The method above described can be implemented in a gas turbine engine 1 comprising a compressor 2, a combustion chamber 3 and a turbine 4.

[0019] The combustion chamber 3 has a fuel supply line 6 with a heat exchanger 7 for adjusting a natural gas temperature (i.e. to pre-heat the natural gas that is supplied through the line 6 to the combustion chamber 3 of the gas turbine 1).

[0020] The heat exchangers can be of different types and can be supplied with different warm fluids such as for example steam, warm air from the cooling air cooler or warm water.

[0021] In addition, the gas turbine engine 1 has a sensor 9 for measuring by infrared analysis the natural gas percentage content of methane (CH_4), ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), carbon dioxide (CO_2); since infrared analysis is used this measure is very fast (seconds).

[0022] The sensor 9 is connected to a controller 10 for calculating the percentage content of nitrogen (N_2) as the complement to 100 of the measured percentage content of methane (CH_4), ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), carbon dioxide (CO_2).

[0023] In addition, the controller 10 also calculates an index indicative of the natural gas energy content and on the basis of this index the controller 10 drives actuators for the heat exchanger to adjust the natural gas temperature.

[0024] The actuators are usually defined by valves that regulate the steam flow or warm air flow or warm water flow. Other kinds of actuators are possible.

[0025] When the method is implemented in a gas turbine engine like the one described, look up tables can be used.

[0026] Thus, if the calculated NGI is for example 0.75, the maximum temperature for the natural gas to be injected into the combustion chamber 3 of the gas turbine engine of figure 1 is a given temperature according to the look up table. The natural gas will be pre-heated at this given temperature or at a temperature lower than this given temperature.

[0027] The method can also be used in gas turbine engine with sequential combustion.

[0028] Figure 2 shows a gas turbine engine with sequential combustion; in figure 2 like reference numbers as in figure 1 indicates the same or similar components, i.e. the gas turbine engine 1 has the compressor 2, the combustion chamber 3, the turbine 4, the heat exchanger 7, the sensor 9 and the controller 10.

[0029] In addition, the gas turbine engine 1 includes a sequential combustion chamber 15 that is supplied with the flue gases from the turbine 4 and a second turbine 16 to expand hot gases generated in the sequential combustion chamber 15.

[0030] In this example, the fuel supply line of the combustion chamber 3 is indicated by the reference 6a and the fuel supply line of the sequential combustion chamber is indicated by the reference 6b.

[0031] The fuel supply line 6b has a heat exchanger 17 for adjusting the natural gas temperature.

[0032] The controller 10 drives the actuators of the heat exchanger 7 of the fuel supply line 6a of the combustion chamber 3 independently of the actuators of the heat exchanger 17 of the fuel supply line 6b of the sequential combustion chamber 15.

[0033] When the method is implemented in a gas turbine engine like the one described, look up tables can be used.

[0034] Thus, if the calculated NGI is for example 0.75, the maximum temperature for the natural gas to be injected into the combustion chamber 3 is a given temperature and the maximum temperature for the natural gas to be injected into the combustion chamber 15 is this given temperature.

[0035] The operation of the gas turbine engine is apparent from that described and illustrated and is substantially the following (with reference to figure 2).

[0036] Air is compressed in the compressor 2 and supplied into the combustion chamber 3 in which also natural gas is supplied. The natural gas is combusted generating hot gas that is expanded in the turbine 4. The exhaust gas from the turbine 4 is supplied into the sequential combustion chamber 15 where additional natural gas is provided and combusted generating hot gas. This hot gas is expanded in the second turbine 16 and is then discharged.

[0037] A common line supplies fuel to the fuel supply lines 6a and 6b. The sensor 9 measures the content (percentage) of methane, ethane, propane, butane, carbon dioxide; this measure is very fast (seconds). The information on the percentage content of methane, ethane, propane, butane, carbon dioxide is provided to the controller 10 that calculates the content (percentage) of nitrogen and the molecular weight of a mixture having the measured percentage of methane, ethane, propane, butane, carbon dioxide and the calculated percentage of nitrogen. The total amount will not be exactly 100%, but this does not affect the adjustment.

[0038] Then the index NGI is calculated and for example on the basis of look up tables the maximum temperature for the natural gas supplied to the combustion chamber 3 and sequential combustion chamber 15 is found (these temperature are in general different but could also be the same).

[0039] The temperature of the natural gas must not be higher than the maximum temperature found, i.e. the temperature of the natural gas can be lower than the maximum temperature, but for efficiency reasons, preferably the temperature of the natural gas (pre-heating) is adjusted to the maximum temperature or to a value close to it.

[0040] Naturally the features described may be independently provided from one another.

[0041] In practice the materials used and the dimensions can be chosen at will according to requirements and to the state of the art.

REFERENCE NUMBERS

1	gas turbine engine
2	compressor
3	combustion chamber
4	turbine
6	fuel supply line
6a, 6b	fuel supply line
7	heat exchanger
9	sensor
10	controller
15	sequential combustion chamber
16	second turbine
17	heat exchanger

Claims

1. A method for adjusting a natural gas temperature for a fuel supply line (6) of a gas turbine engine (1), the method comprising:

measuring by infrared analysis the natural gas percentage content of methane (CH4), ethane (C2H6), propane (C3H8), butane (C4H10), carbon dioxide (CO2),
calculating the nitrogen (N2) percentage content as the complement to 100 of the measured percentage content of methane (CH4), ethane (C2H6), propane (C3H8), butane (C4H10), carbon dioxide (CO2),
calculating an index indicative of the natural gas energy content,
adjusting the natural gas temperature on the basis of the index.

2. The method of claim 1, **characterised in that** adjusting the natural gas temperature includes:

defining a plurality of ranges for the index,
associating one maximum temperature to each range,
maintaining the natural gas temperature below or at the maximum temperature corresponding to the range into which the calculated index falls.

3. The method of claim 1, **characterised in that** the index is calculated by:

calculating the lower heat value of a mixture including the measured amount of methane (CH4), ethane (C2H6), propane (C3H8), butane (C4H10), carbon dioxide (CO2) and the calculated amount of nitrogen (N2),
calculating the molecular weight of the mixture including the measured amount of methane (CH4), ethane (C2H6), propane (C3H8), butane (C4H10), carbon dioxide (CO2) and the calculated amount of nitrogen (N2),
calculating the index either by

$$NGI = (LHVng/LHVch4) * (Mng/Mch4)^{1/2}$$

or

$$NGI = (LHVng/LHVdes) * (Mng/Mdes)^{1/2}$$

wherein
LHVng is the calculated lower heat value of the mixture,
LHVch4 is the lower heat value of methane,
LHVdes is the design lower heat value,
Mng is the molecular weight of the mixture,
Mch4 is the molecular weight of methane,
Mdes is the design molecular weight.

4. The method of claim 1, **characterised in that**:

the gas turbine engine (1) has a plurality of fuel supply lines (6a, 6b) for different combustion chambers (3, 15) and/or different stages of a combustion chamber,
the natural gas temperature of at least one fuel supply line (6a) is adjusted independently of the natural gas temperature of another fuel supply line (6b).

5. A gas turbine engine (1) comprising a compressor (2), a combustion chamber (3) and a turbine (4), the combustion chamber (3) having a fuel supply line (6) with a heat exchanger (7) for adjusting a natural gas temperature, the gas turbine engine (1) further including:

at least a sensor (9) for measuring by infrared analysis the natural gas percentage content of methane (CH_4), ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), carbon dioxide (CO_2), and
a controller (10) for calculating the percentage content of nitrogen (N_2) as the complement to 100 of the measured percentage content of methane (CH_4), ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), carbon dioxide (CO_2),
the controller (10) for further calculating an index indicative of the natural gas energy content and on the basis thereof drive actuators for the heat exchanger (7) to adjust the natural gas temperature on the basis of the index.

6. The gas turbine engine of claim 5, **characterised by** including:

a sequential combustion chamber (15) that is supplied with the flue gases from the turbine (4), and
a second turbine (16) to expand hot gases generated in the sequential combustion chamber (15),
wherein the sequential combustion chamber (15) has a fuel supply line (6b) with a heat exchanger (17) for adjusting the natural gas temperature, and
the controller (10) drives the actuators of the heat exchanger (7) of the fuel supply line (6a) of the combustion chamber (3) independently of the actuators of the heat exchanger (17) of the fuel supply line (6b) of the sequential combustion chamber (15).

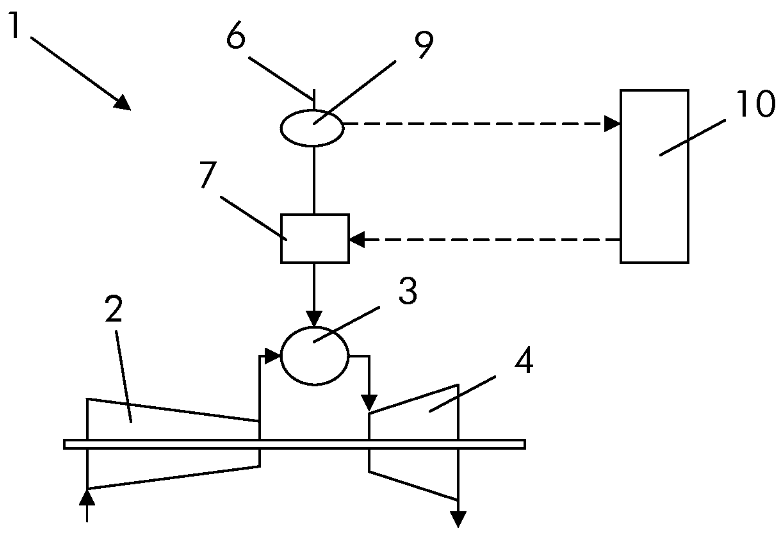

Fig. 1

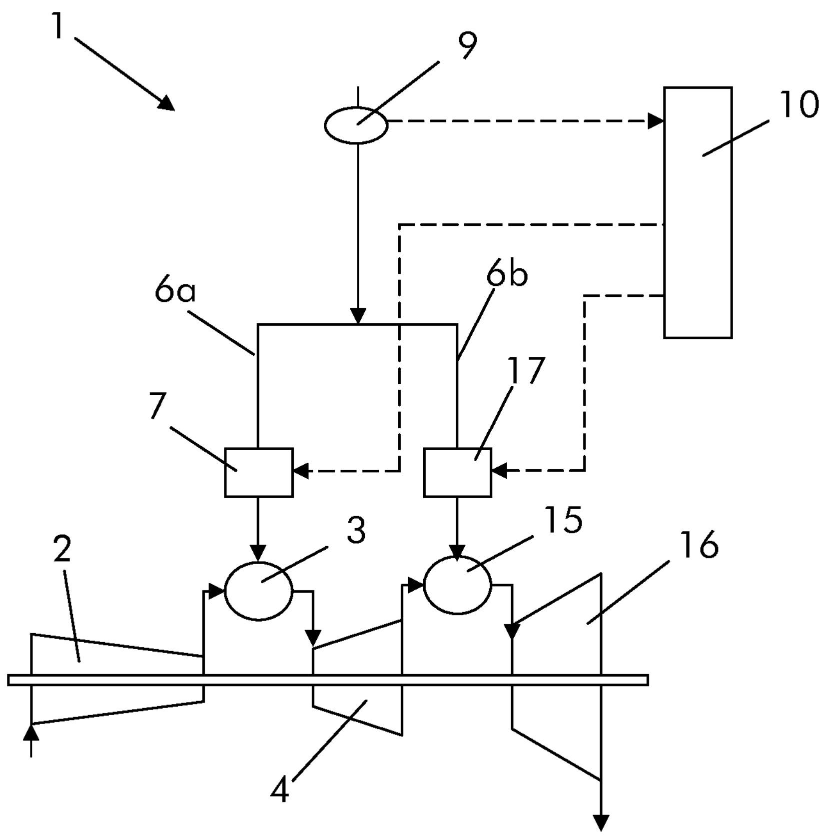

Fig. 2

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 13 15 6508

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	EP 2 557 297 A1 (ALSTOM TECHNOLOGY LTD [CH]) 13 February 2013 (2013-02-13) * paragraphs [0002], [0017], [0027], [0030], [0038] *	1,5	INV. F02C7/224 F02C9/00 F02C9/40 G01N33/22
Y	EP 2 204 561 A2 (GEN ELECTRIC [US]) 7 July 2010 (2010-07-07) * paragraphs [0025], [0027], [0028], [0032], [0035] *	1,5	
A	US 6 082 092 A (VANDERVORT CHRISTIAN L [US]) 4 July 2000 (2000-07-04) * column 1, lines 45-61 * * column 3, lines 2-16,24-38 * * column 5, lines 12-31 *	1,5	
A	US 2008/115482 A1 (LAGROW MATTHEW J [US] ET AL) 22 May 2008 (2008-05-22) * paragraphs [0026], [0028] - [0031]; claim 1 *	1-6	TECHNICAL FIELDS SEARCHED (IPC)
A	DE 103 02 487 A1 (ALSTOM SWITZERLAND LTD [CH]) 31 July 2003 (2003-07-31) * the whole document *	1-6	F02C G01N

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	16 October 2013	Steinhauser, Udo

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
& : member of the same patent family, corresponding document

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 13 15 6508

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

16-10-2013

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
EP 2557297	A1	13-02-2013	CN	102953821	A	06-03-2013
			EP	2557297	A1	13-02-2013
			US	2013036744	A1	14-02-2013
EP 2204561	A2	07-07-2010	CN	101793196	A	04-08-2010
			EP	2204561	A2	07-07-2010
			JP	2010156324	A	15-07-2010
			US	2010162678	A1	01-07-2010
US 6082092	A	04-07-2000	JP	3022882	B2	21-03-2000
			JP	H11324727	A	26-11-1999
			TW	487795	B	21-05-2002
			US	6082092	A	04-07-2000
US 2008115482	A1	22-05-2008	NONE			
DE 10302487	A1	31-07-2003	CN	1623031	A	01-06-2005
			DE	10302487	A1	31-07-2003
			EP	1472447	A1	03-11-2004
			JP	4495971	B2	07-07-2010
			JP	2005515358	A	26-05-2005
			US	2005028530	A1	10-02-2005
			WO	03062618	A1	31-07-2003

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82